AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCLIV.

(Vol. XII.—April, 1883.)

THE FLOW OF WATER THROUGH PIPES.

By HAMILTON SMITH, JR., M. Am. Soc. C. E.

READ MARCH 7TH, 1883.*

The following table gives the results of 88 experiments as to the discharge of water through circular pipes, ranging from 4 feet to ½ inch in diameter, and with velocities varying from 20 feet to ⅛th of a foot per second. The pipes were of rolled and cast iron, glass and wood; their interior surfaces varied from the almost perfect smoothness of glass to the roughness of old iron, much incrusted by the continued action of soft water.

Of the 88 experiments given, 71 were made by the writer of this paper, and 18 have been selected from standard authorities, for the purpose of more extended comparison.

Experiments Nos. 1 to 15, inclusive, &c., were made at North Bloomfield, California, with three pipes laid side by side across a ravine about 100 feet lower than the penstock. They were made of single-riveted No. 14 sheet iron; the rivet heads had worn pretty smooth, and no deduction for them was made in computing the areas. The pipes had been care-

* The discussion upon this paper will be published in a future issue of the Transactions.

fully coated when first laid with a mixture of coal tar and asphaltum, and their interior surfaces at the time of these measurements were quite smooth. They were put together in slightly conical joints, the greatest variation in diameter being about $\frac{1}{4}$th of an inch. The main joints were some 20 feet in length, put together stove-pipe fashion, as is always done in the California hydraulic mines. The various heads were obtained by adding to the length of the pipes at their outlet.

The heads, lengths and mean diameters are given with exactness. The amount of discharge was measured by running the water over an iron weir, the co-efficients of whose discharge, with varying depths, had been carefully determined by absolute measurement, but at another point, and under conditions not exactly similar. This gauging was done with all the care practicable, the height of the water being measured with a Boyden hook gauge, reading to .001 of an inch. The limit of possible error in these experiments is probably not over 2 per cent.

Experiments Nos. 6 and 7, however, are somewhat unreliable, owing to the stoppage of a stone passing through the pipe.

The co-efficient of contraction is assumed at 1. in these pipes, as each of them had a short funnel-shaped inlet, which was included in the measurement of their lengths.

In Nos. 1, 6 and 10, the discharge was into a pool of water at the outlet box; in the other 12 the discharge was into the air.

There were two angles in the line of these pipes, one of 9° and the other of 11° ; for the remainder of the distance they were nearly straight; in the computations no deduction was made for these bends.

No. 17 is based chiefly upon data given to the writer by the engineers who had the hydraulic works of the Spring Valley Mining Company in Butte County, California, in charge. It may be incidentally observed that this pipe was laid in 1870, and has remained in perfect condition ever since its construction. It is made of double-riveted sheet iron, having a thickness of $\frac{3}{8}$ths of an inch at the point of greatest pressure, where the actual head is 887 feet. The maximum tensile strain on the iron is 17.549 lbs. per square inch.

The rivet heads for one-half the length of the pipe, no doubt, perceptibly retarded the flow of water.

Round stones weighing about 25 lbs. passed through the pipe with a velocity of 9.0 feet per second, while the computed velocity of the water was 10.78 feet.

FLOW OF WATER THROUGH CIRCULAR PIPES. FORMULA $V = m\left(\frac{d\,h'}{l}\right)^{\frac{1}{2}}$ EXPRESSED IN ENGLISH FEET.

No. of Experiment.	l Length.	d Mean Diameter.	a Mean Area.	h Total Head.	c Co-efficient of Contraction	$2g$ Gravity.	h' Effective Head.	D Discharge per Second.	V Velocity per Second.	Velocity of Stones sent through Pipe.	m Variable Co-efficient.	No. of Experiment.	AUTHORITY.	REMARKS.
1	684.8	.9105	.6511	24.220	1.00	64.29	22.650	6.542	10.048	9.42	57.90	1	Hamilton Smith, Jr., North Bloomfield.	Experiments 1 to 15 inclusive were with riveted sheet-iron pipes of No. 14 iron, coated with coal tar and asphaltum, and having been in use some 5 or 6 years; these three pipes were laid side by side across a valley about 100 feet lower than inlets, with no very sharp curves or angles. Pipes all fairly smooth, and joints put together stove-pipe fashion.
2	697.0	.911	.6518	19.005	do.	do.	17.832	5.661	8.685	.....	56.89	2	do. do.	
3	713.9	.911	.6518	12.850	do.	do.	12.098	4.631	6.952	5.79	55.95	3	do. do.	
4	721.3	.911	.6518	10.200	do.	do.	9.618	3.986	6.115	.....	55.49	4	do. do.	
5	730.6	.911	.6518	6.555	do.	do.	6.203	3.099	4.755	.....	54.06	5	do. do.	
6	684.9	1.056	.8758	24.510	do.	do.	22.711	9.419	10.755	.....	57.47	6	do. do.	
7	699.6	1.056	.8758	16.690	do.	do.	15.519	7.601	8.679	7.4 (?)	56.71	7	do. do.	
8	709.2	1.056	.8758	10.885	do.	do.	10.127	6.115	6.982	.....	56.86	8	do. do.	
9	718.4	1.056	.8758	5.130	do.	do.	4.799	4.039	4.612	.....	54.91	9	do. do.	
10	684.4	1.230	1.1882	24.390	do.	do.	22.036	14.617	12.302	11.88	61.82	10	do. do.	
11	695.6	1.230	1.1882	18.930	do.	do.	17.132	12.773	10.750	9.58	61.76	11	do. do.	
12	705.0	1.230	1.1882	12.720	do.	do.	11.592	10.120	8.517	.....	59.89	12	do. do.	
13	716.7	1.230	1.1882	9.550	do.	do.	8.713	8.714	7.334	.....	59.72	13	do. do.	
14	712.4	1.230	1.1882	8.545	do.	do.	7.813	8.152	6.861	.....	59.07	14	do. do.	
15	719.9	1.229	1.1863	3.915	do.	do.	3.614	5.217	4.398	....	55.99	15	do. do.	
16	5.280.	4.	12.57	5.	.....	.....	5.	43.46	3.46	.....	56.22	16	J. M. Gale, Inst. Engineers in Scotland. 1869.	Statement by Prof. Rankine. Section of long pipe.
17	12.798.	2.43 (?)	4.64	150.0	.....	.....	150.	50.0	10.78	9.0	63.88	17	Surveys for Spring Valley Mining Co.	Measurements of discharge were 51.5, 48.5 and 52.3 feet per second. Probably 50 feet is nearly correct.
18	1.193.8	2.154	3.643	22.067	1.00	64.29	19.596	45.92	12.605	11.24	67.03	18	Hamilton Smith, Jr., North Bloomfield.	Discharge was not measured with great accuracy.
19	29.580.	1.3333	1.396	420.	.....	.....	420.	9.516	6.816	.....	49.54	19	Institution of Civil Engineers. 1855.	Colinton pipe.
20	25.765.	1.3333	1.396	230.	.....	.....	230.	7.333	5.252	.....	48.14	20	do. do.	do.
21	3.815.	1.3333	1.396	184.	1.00	64.4	180.7	20.25	14.505	.....	57.72	21	do. do.	do.
22	3.836.6	1.599	2.007	12.885	do.	do.	12.697	6.981	3.478	.....	47.81	22	Couplet. Ency. Brit. 8th Ed. "Rivers."	Versailles pipe.
23	7.481.7	.4441	.....	.496	.....	.....	.496	.....	.1786	.....	32.92	23	do. do.	Iron and earthen pipe.
24	7.481.7	.4441	.....	1.007	.....	.....	1.007	.....	.2801	.....	36.23	24	do. do.	do.
25	7.481.7	.4441	.....	1.488	.....	.....	1.488	.....	.3665	.....	39.00	25	do. do.	do.
26	7.481.7	.4441	.....	1.872	.....	.....	1.872	.....	.4268	.....	40.49	26	do. do.	do.
27	7.481.7	.4441	.....	2.132	.....	.....	2.132	.....	.4629	.....	41.15	27	do. do.	do.
28	7.481.7	.4441	.....	2.220	.....	.....	2.220	.....	.4728	.....	41.19	28	do. do.	do.
29	50.776.	3.	7.0686	16.517 | 143.720	.....	.....	27.00 | 143.72	14.360	2.0315	.....	65.031	29	Report of Engineer Rochester Water Works.	Hemlock lake compound pipe, made of cast and wrought iron.
30	51.495.	2.	3.1416	127.203	.....	.....	116.72		4.5709	.....		30		
31	11.217.	3.	7.069	20.215	.....	.....	20.215	21.204	3.00	.....	40.8	31	James P. Kirkwood, Brooklyn Water Works.	Croton main, New York City, much incrusted by soft water.
32	29.715.	1.6667	2.182	30.262	.....	.....	30.262	3.256	1.492	.....	36.22	32	do. do.	Jersey City main. Comparatively new pipe(?), but much incrusted.
33	44.400.	1.25	1.227	226.	.....	.....	226.	4.25	3.46	.....	43.4	33	Institution of Civil Engineers.	Crawley pipe.
34	6.600.	1.	.7854	34.5	1.00	64.4	34.3	.....	3.568	.....	49.5	34	do.	Carlisle pipe.
35	60.172	.0878	.006054	8.330	.800	64.287	7.641	.03224	5.325	.....	50.43	35		
36	60.172	.0878	.006054	6.590	do.	do.	6.059	.02829	4.673	.....	49.70	36		
37	60.172	.0878	.006054	4.850	do.	do.	4.471	.02390	3.948	.....	48.88	37		
38	60.172	.0878	.006054	3.272	do.	do.	3.027	.01922	3.175	.....	47.77	38	Hamilton Smith, Jr., New Almaden.	One-inch new gas pipe, untarred, and no funnel.
39	60.172	.0878	.006054	1.663	do.	do.	1.550	.01304	2.154	.....	45.29	39		
40	60.172	.0878	.006054	.787	do.	do.	.738	.00860	1.421	.....	43.30	40		
41	60.172	.0878	.006054	.473	do.	do.	.451	.00580	.958	.....	37.34	41		
42	60.247	.0878	.006054	8.317	.980	do.	7.847	.03261	5.387	.....	50.38	42		
43	60.247	.0878	.006054	6.506	do.	do.	6.147	.02850	4.708	.....	49.74	43		
44	60.247	.0878	.006054	4.847	do.	do.	4.588	.02421	3.999	.....	48.91	44		
45	60.247	.0878	.006054	3.276	do.	do.	3.107	.01953	3.226	.....	47.94	45	do. do.	One-inch new gas pipe, untarred, and funnel at mouth.
46	60.247	.0878	.006054	1.669	do.	do.	1.591	.01331	2.199	.....	45.67	46		
47	60.247	.0878	.006054	.784	do.	do.	.751	.00869	1.435	.....	43.38	47		
48	60.247	.0878	.006054	.491	do.	do.	.473	.00637	1.052	.....	40.07	48		
49	60.264	.0873	.005986	8.353	do.	do.	7.873	.03258	5.443	.....	50.97	49		
50	60.264	.0873	.005986	6.597	do.	do.	6.230	.02850	4.761	.....	50.12	50		
51	60.264	.0873	.005986	3.313	do.	do.	3.145	.01930	3.234	.....	47.77	51		
52	60.264	.0873	.005986	1.703	do.	do.	1.623	.01329	2.220	.....	45.78	52	do. do.	One-inch new gas pipe, tarred, with funnel.
53	16.685	.0876	.006027	4.620	do.	do.	3.853	.04148	6.882	.....	48.39	53		
54	16.685	.0876	.006027	3.179	do.	do.	2.667	.03388	5.621	.....	47 50	54		
55	16.685	.0876	.006027	1.514	do.	do.	1.283	.02275	3.775	.....	46.00	55		
56	16.685	.0876	.006027	.623	do.	do.	.535	.01406	2.333	.....	44.02	56		
57	60.247	.0853	.005715	8.315	do.	do.	8.020	.02438	4.266	.....	40.03	57		
58	60.247	.0853	.005715	6.563	do.	do.	6.332	.02156	3.773	.....	39.85	58		
59	60.247	.0853	.005715	4.846	do.	do.	4.679	.01835	3.211	.....	39.45	59		
60	60.247	.0853	.005715	3.278	do.	do.	3.167	.01497	2.619	.....	39.11	60	do. do.	One-inch gas pipe, with funnel; pipe had been several years in use.
61	60.247	.0853	.005715	1.684	do.	do.	1.630	.01045	1.829	.....	38.07	61		
62	60.247	.0853	.005715	.780	do.	do.	.757	.00683	1.195	.....	36.50	62		
63	60.247	.0853	.005715	.474	do.	do.	.461	.00520	.910	.....	35.62	63		
64	60.127	.0523	.002148	8.354	.825	do.	8.010	.00833	3.878	.....	46.46	64		
65	60.127	.0523	.002148	6.593	do.	do.	6.331	.00727	3.385	.....	45.62	65		
66	60.127	.0523	.002148	4.867	do.	do.	4.680	.00615	2.863	.....	44.87	66	do. do.	Five-eighths-inch new gas pipe, no funnel.
67	60.127	.0523	.002148	3.306	do.	do.					43.60	67		

6	682.9	1.056	.8758	16.690	do.	do.	15.519	14.601	[illegible]	.....	56.86	8	do.	do.	across a valley about 100 feet lower than theirs, with [illegible]
7	699.6	1.056	.8758	16.690	do.	do.	15.519	14.601	[illegible]	.....	56.86	8	do.	do.	
8	709.2	1.056	.8758	10.885	do.	do.	10.127	6.115	6.982	.....	54.91	9	do.	do.	
9	718.4	1.056	.8758	5.130	do.	do.	4.799	4.039	4.612	.....					fairly smooth, and joints put together stove-pipe fashion.
10	684.4	1.230	1.1882	24.390	do.	do.	22.036	14.617	12.302	11.88	61.82	10	do.	do.	
11	695.6	1.230	1.1882	18.930	do.	do.	17.132	12.773	10.750	9.58	61.76	11	do.	do.	
12	705.0	1.230	1.1882	12.720	do.	do.	11.592	10.120	8.517	.....	59.89	12	do.	do.	
13	710.7	1.230	1.1882	9.550	do.	do.	8.713	8.714	7.334	.....	59.72	13	do.	do.	
14	712.4	1.230	1.1882	8.545	do.	do.	7.813	8.152	6.861	.....	59.07	14	do.	do.	
15	719.9	1.229	1.1863	3.915	do.	do.	3.614	5.217	4.398	....	55.99	15	do.	do.	
16	5.280.	4.	12.57	5.	.....	.....	5.	43.46	3.46	.....	56.22	16	J. M. Gale, Inst. Engineers in Scotland.	1869.	Statement by Prof. Rankine. Section of long pipe.
17	12.798.	2.43 (?)	4.64	150.0	.....	.....	150.	50.0	10.78	9.0	63.88	17	Surveys for Spring Valley Mining Co.		Measurements of discharge were 51.5, 48.5 and 52.8 feet per second. Probably 50 feet is nearly correct.
18	1.193.8	2.154	3.643	22.067	1.00	64.29	19.596	45.92	12.605	11.24	67.03	18	Hamilton Smith, Jr., North Bloomfield.		Discharge was not measured with great accuracy.
19	29.580.	1.3333	1.396	420.	.....	.....	420.	9.516	6.816	.....	49.54	19	Institution of Civil Engineers.	1855.	Colinton pipe.
20	25.765.	1.3333	1.396	230.	.....	.....	230.	7.333	5.252	.....	48.14	20	do.		do.
21	3.815.	1.3333	1.396	184.	1.00	64.4	180.7	20.25	14.505	.....	57.72	21	do.		do.
22	3.836.6	1.599	2.007	12.885	do.	do.	12.697	6.981	3.478	.....	47.81	22	Couplet. Ency. Brit.	8th Ed. "Rivers."	Versailles pipe.
23	7.481.7	.4441	.....	.496	.....	.....	.496	.....	.1786	.....	32.92	23	do.	do.	Iron and earthen pipe.
24	7.481.7	.4441	.....	1.007	.....	.....	1.007	.....	.2801	.....	36.23	24	do.	do.	do.
25	7.481.7	.4441	.....	1.488	.....	.....	1.488	.....	.3665	.....	39.00	25	do.	do.	do.
26	7.481.7	.4441	.....	1.872	.....	.....	1.872	.....	.4268	.....	40.49	26	do.	do.	do.
27	7.481.7	.4441	.....	2.132	.....	.....	2.132	.....	.4629	.....	41.15	27	do.	do.	do.
28	7.481.7	.4441	.....	2.220	.....	.....	2.220	.....	.4728	.....	41.19	28	do.	do.	do.
29	50.776.	3.	7.0686	16.517	143.720	.....	.....	27.00	143.72	14.360	2.0315	.....	65.031	29	Report of Engineer Rochester Water Works.	Hemlock lake compound pipe, made of cast and wrought iron.
30	51.495.	2.	3.1416	127.203		.....	.....	116.72			4.5709	.....		30		
31	11.217.	3.	7.069	20.215		.....	.....	20.215		21.204	3.00	.....	40.8	31	James P. Kirkwood, Brooklyn Water Works.	Croton main, New York City, much incrusted by soft water.
32	29.715.	1.6667	2.182	30.262		.....	.....	30.262		3.256	1.492	.....	36.22	32	do. do.	Jersey City main. Comparatively new pipe(?), but much incrusted.
33	44.400.	1.25	1.227	226.		.....	.....	226.		4.25	3.46	.....	43.4	33	Institution of Civil Engineers.	Crawley pipe.
34	6.600.	1.	.7854	34.5	1.00	64.4	34.3	.....			3.568	.....	49.5	34	do.	Carlisle pipe.
35	60.172	.0878	.006054	8.330	.800	64.287	7.641	.03224			5.325	.....	50.43	35		
36	60.172	.0878	.006054	6.590	do.	do.	6.059	.02829			4.673	.....	49.70	36		
37	60.172	.0878	.006054	4.850	do.	do.	4.471	.02390			3.948	.....	48.88	37		
38	60.172	.0878	.006054	3.272	do.	do.	3.027	.01922			3.175	.....	47.77	38	Hamilton Smith, Jr., New Almaden.	One-inch new gas pipe, untarred, and no funnel.
39	60.172	.0878	.006054	1.663	do.	do.	1.550	.01304			2.154	.....	45.29	39		
40	60.172	.0878	.006054	.787	do.	do.	.738	.00860			1.421	.....	43.30	40		
41	60.172	.0878	.006054	.473	do.	do.	.451	.00580			.958	.....	37.34	41		
42	60.247	.0878	.006054	8.317	.980	do.	7.847	.03261			5.387	.....	50.38	42		
43	60.247	.0878	.006054	6.506	do.	do.	6.147	.02850			4.708	.....	49.74	43		
44	60.247	.0878	.006054	4.847	do.	do.	4.588	.02421			3.999	.....	48.91	44		
45	60.247	.0878	.006054	3.276	do.	do.	3.107	.01953			3.226	.....	47.94	45	do. do.	One-inch new gas pipe, untarred, and funnel at mouth.
46	60.247	.0878	.006054	1.669	do.	do.	1.591	.01331			2.199	.....	45.67	46		
47	60.247	.0878	.006054	.784	do.	do.	.751	.00869			1.435	.....	43.38	47		
48	60.247	.0878	.006054	.491	do.	do.	.473	.00637			1.052	.....	40.07	48		
49	60.264	.0873	.005986	8.353	do.	do.	7.873	.03258			5.443	.....	50.97	49		
50	60.264	.0873	.005986	6.597	do.	do.	6.230	.02850			4.761	.....	50.12	50		
51	60.264	.0873	.005986	3.313	do.	do.	3.145	.01930			3.224	.....	47.77	51		
52	60.264	.0873	.005986	1.703	do.	do.	1.623	.01329			2.220	.....	45.78	52	do. do.	One-inch new gas pipe, tarred, with funnel.
53	16.685	.0876	.006027	4.620	do.	do.	3.853	.04148			6.882	.....	48.39	53		
54	16.685	.0876	.006027	3.179	do.	do.	2.667	.03388			5.621	.....	47 50	54		
55	16.685	.0876	.006027	1.514	do.	do.	1.283	.02275			3.775	.....	46.00	55		
56	16.685	.0876	.006027	.623	do.	do.	.535	.01406			2.333	.....	44.02	56		
57	60.247	.0853	.005715	8.315	do.	do.	8.020	.02438			4.266	.....	40.03	57		
58	60.247	.0853	.005715	6.563	do.	do.	6.332	.02156			3.773	.....	39.85	58		
59	60.247	.0853	.005715	4.846	do.	do.	4.679	.01835			3.211	.....	39.45	59		
60	60.247	.0853	.005715	3.278	do.	do.	3.167	.01497			2.619	.....	39.11	60	do. do.	One-inch gas pipe, with funnel; pipe had been several years in use.
61	60.247	.0853	.005715	1.684	do.	do.	1.630	.01045			1.829	.....	38.07	61		
62	60.247	.0853	.005715	.780	do.	do.	.757	.00683			1.195	.....	36.50	62		
63	60.247	.0853	.005715	.474	do.	do.	.461	.00520			.910	.....	35.62	63		
64	60.127	.0523	.002148	8.354	.825	do.	8.010	.00833			3.878	.....	46.46	64		
65	60.127	.0523	.002148	6.593	do.	do.	6.331	.00727			3.385	.....	45.62	65		
66	60.127	.0523	.002148	4.867	do.	do.	4.680	.00615			2.863	.....	44.87	66	do. do.	Five-eighths-inch new gas pipe, no funnel.
67	60.127	.0523	.002148	[illegible]	do.	do.	[illegible]	[illegible]			[illegible]		43.60	67		
70	63.902	.0764	.004584	8.670	.970	do.	8.255	.02296			5.009	.....	50.42	70		
71	63.902	.0764	.004584	6.840	do.	do.	6.522	.02009			4.383	.....	49.64	71		
72	63.902	.0764	.004584	5.036	do.	do.	4.812	.01689			3.685	.....	48.58	72	do. do.	One-inch glass pipe, with funnel.
73	63.902	.0764	.004584	3.387	do.	do.	3.244	.01350			2.945	.....	47.29	73		
74	63.902	.0764	.004584	1.661	do.	do.	1.598	.00896			1.955	.....	44.73	74		
75	34.941	.0622	.003039	5.072	.820	do.	4.630	.01329			4.373	.....	48.17	75		
76	34.941	.0622	.003039	3.660	do.	do.	3.349	.01114			3.666	.....	47.48	76	do. do.	Three-fourths-inch glass pipe, no funnel.
77	34.941	.0622	.003039	2.059	do.	do.	1.896	.00806			2.652	.....	45.65	77		
78	34.941	.0622	.003039	0.673	do.	do.	.628	.00425			1.398	.....	41.81	78		
79	11.127	.0418	.001372	3.025	do	do.	2.569	.00609			4.439	.....	45.19	79		
80	11.127	.0418	.001372	2.155	do.	do.	1.846	.00502			3.659	.....	43.94	80	do. do.	One-half-inch glass pipe, no funnel.
81	11.127	.0418	.001372	1.266	do.	do.	1.095	.00373			2.719	.....	42.39	81		
82	11.127	.0418	.001372	.816	do.	do	.716	.00285			2.077	.....	40.05	82		
83	62.05	.1052	.008692	8.524	.800	do.	8.138	.03465			3.986	.....	33.93	83		
84	62.05	.1052	.008692	6.696	do.	do.	6.395	.03059			3.519	.....	33.80	84		
85	62.05	.1052	.008692	4.942	do.	do.	4.722	.02615			3.008	.....	33.62	85	do. do.	Wooden one-and-a-quarter-inch pipe, no funnel.
86	62.05	.1052	.008692	3.309	do.	do.	3.161	.02146			2.469	.....	33.73	86		
87	62.05	.1052	.008692	1.567	do.	do.	1.501	.01437			1.653	.....	32.77	87		
88	4.438.7	1.416	1.571	303.6	.920	64.4	296.1	31.69		20.13	20.9		65.56	88	do. Texas Creek.	Pipe carefully tarred and comparatively new.

No. 18 was a single-riveted sheet-iron pipe, with the interior surface worn quite smooth, and with joints put together stove-pipe fashion.

The mean diameter, head and length, are given with exactness; the discharge was measured through a series of apertures, no great accuracy being practicable.

The limit of possible error in this case may be as much as 4 per cent.

Nos. 22 to 28, inclusive, are the early experiments of Couplet, and seem to be reliable.

The authorities for Nos. 16, 19 to 21, and 29 to 34, inclusive, are given in the table.

Nos. 29 and 30, being the Rochester supply main of two different diameters, show an apparently excessive discharge. This was stated to have been directly measured by the filling of a reservoir of known size.

Nos. 31 and 32 are given as illustrations of extremely rough surfaces. Mr. Kirkwood states that in No. 32—the Jersey City main—the pipe was comparatively new, which makes the very low co-efficient of discharge quite remarkable.

Nos. 35 to 87 inclusive were made by the writer at New Almaden, California. All these experiments were with straight pipes, and were made with considerable accuracy.

The mean diameters were computed by the weight of water contained in the pipes, taken by the sum of the weights in the several joints, which varied slightly from the mean of the end diameters as directly measured.

The discharge was determined by filling a tank of known size.

The iron gas-pipes were joined by their usual couplings. The ends of the glass pipes were smoothly ground, and a water-tight joint made by an outside rubber band. The wooden pipe was joined by usual plug couplings.

The funnel mouth-piece for the inch gas-pipe was 10½ inches long, with a mouth 6½ inches in diameter; the funnel for the inch glass pipe was 3½ inches long, with mouth 5 inches in diameter. These mouth-pieces were not included in the given lengths of the pipes.

Nos. 35 to 52 inclusive were made with the same pipe, which was new and in good order; it was first used without a mouth-piece, then with a mouth-piece, and afterwards the pipe was dipped in a bath of boiling coal-tar and asphaltum, giving it a very smooth coating.

Nos. 53 to 56 inclusive were with a shorter section of the same pipe.

The pipe used in Nos. 57 to 63 inclusive had been in use for several years, was rather rusty, and was slightly incrusted by the action of lime water. The method of obtaining the diameter—by the quantity of water contained—gave the exact size of the pipe at the time of the experiments.

The glass pipes used were new and unscratched, of French manufacture, and somewhat conical. There were twelve joints of the inch pipe, which were nearly evenly matched in diameter at the junctions; the largest diameter was .0875′, and the smallest, .0717′.

The measuring tank held 15.2 cubic feet, and the times were determined to $\frac{1}{5}$th of a second.

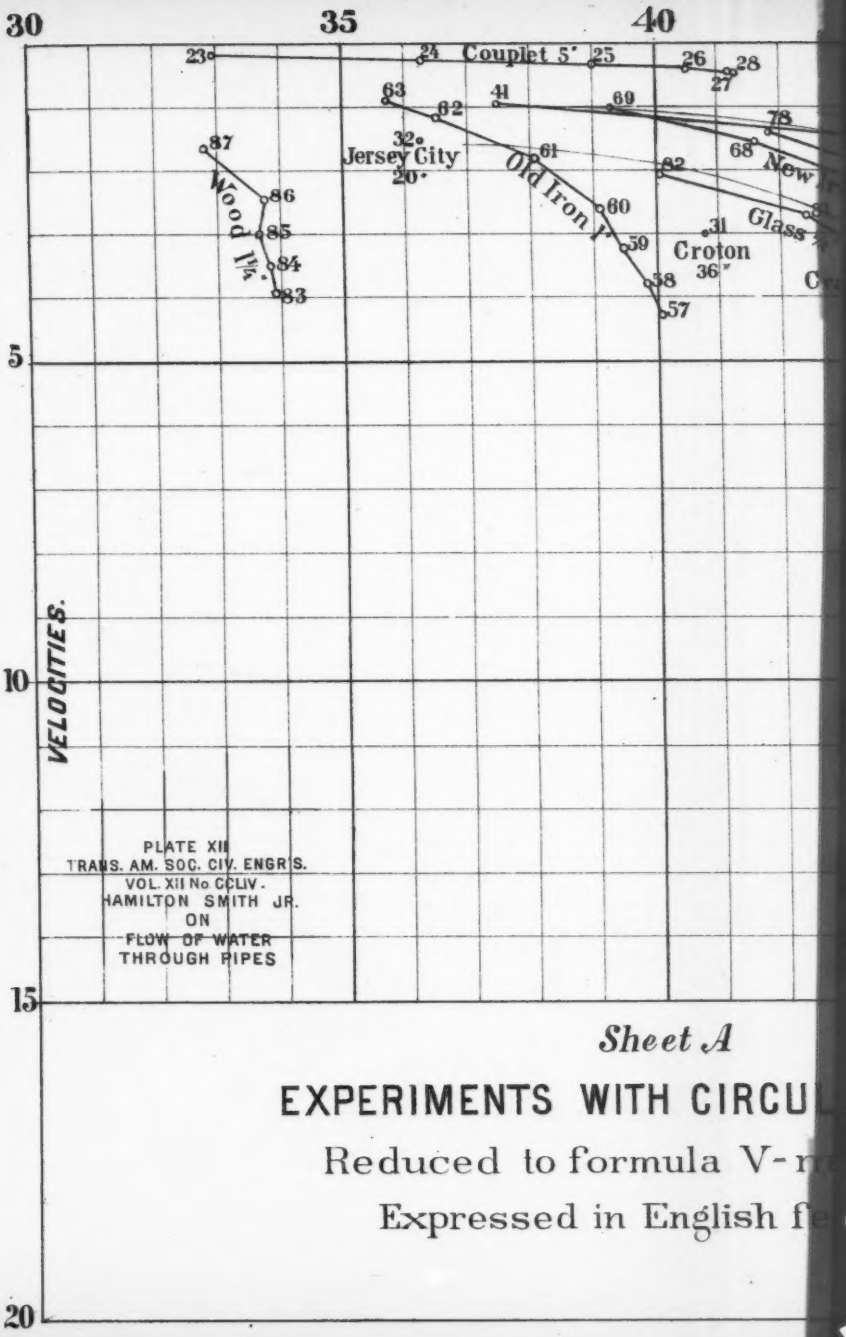
No. 88 was with a new inverted siphon of double-riveted sheet-iron pipe, with a pressure of about 800 feet at the lowest point, with a maximum tensile strain of 16 500 lbs. per square inch, and with most of the joints made by sleeves with lead packing. It was coated with the usual mixture of coal-tar and asphaltum.

No deduction was made for rivet heads, which for over one-half the length doubtless formed noteworthy obstructions, as the pipe was of comparatively small diameter—17 inches.

The mean diameter, head and length, are given with exactness. The discharge was measured first by the flow over a weir, and afterwards through standard apertures; these determinations were not as satisfactory as could have been desired, although three separate trials gave nearly identical results. The chances are that the discharge was slightly underestimated.

A noticeable feature in this experiment is the fact that blocks of wood, loaded to a specific gravity of 1.05, passed through it with a velocity of 20.9 feet per second, while the calculated velocity of the water was only 20.13 feet. In several of the other experiments, similar tests always showed a less speed of the blocks of wood or stone than that of the water, which is readily to be accounted for by the blocks striking the rivet heads. In No. 18 there was no noteworthy difference between the velocity of unloaded wooden blocks and that of rough stones.

In all the experiments made by the writer the actual or total head was either the difference in elevation between the surface of the water in the pen-stock and that in the outlet tank, or the difference between the water in the pen-stock and the centre of the escaping jet, where the pipe discharged into the air. Experiments 35 to 87 inclusive were made under the latter condition.

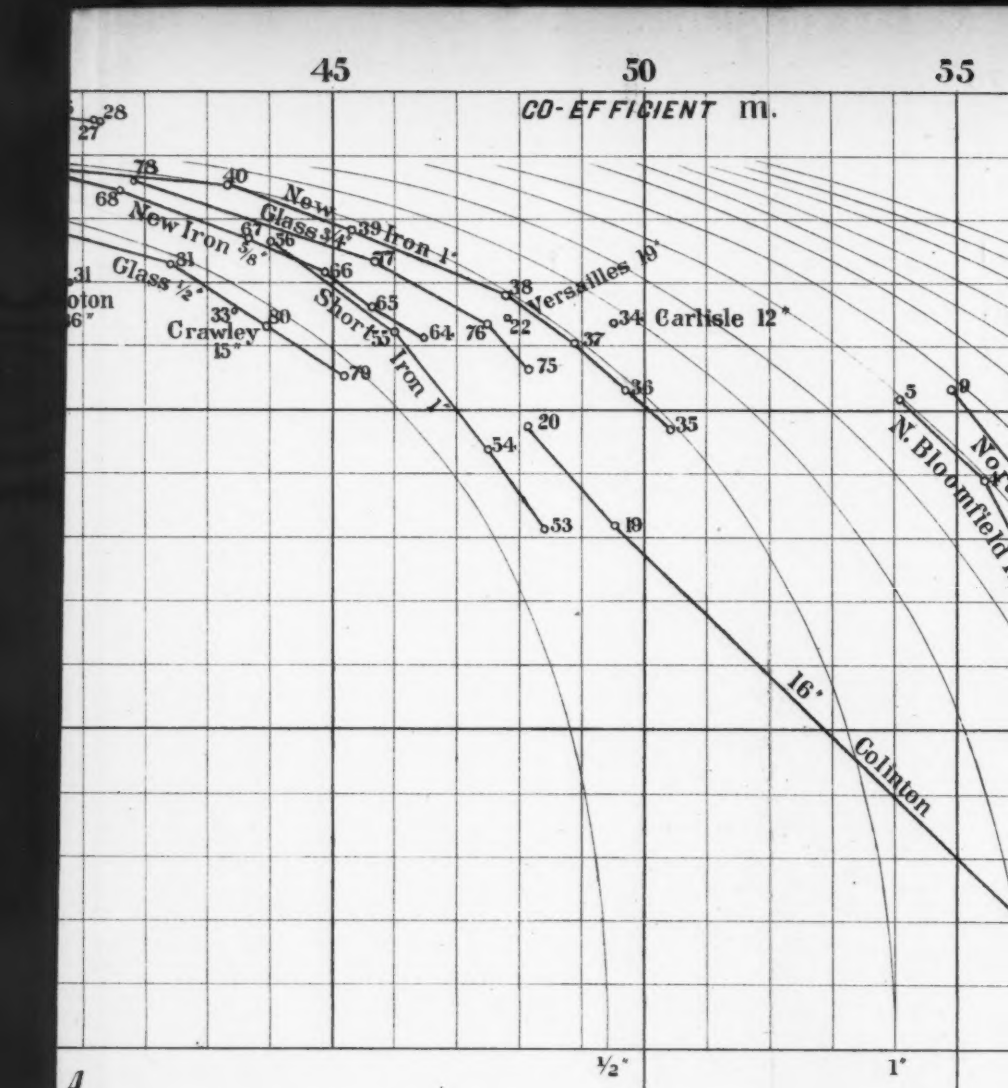


Sheet A

EXPERIMENTS WITH CIRCU

Reduced to formula V-n

Expressed in English f

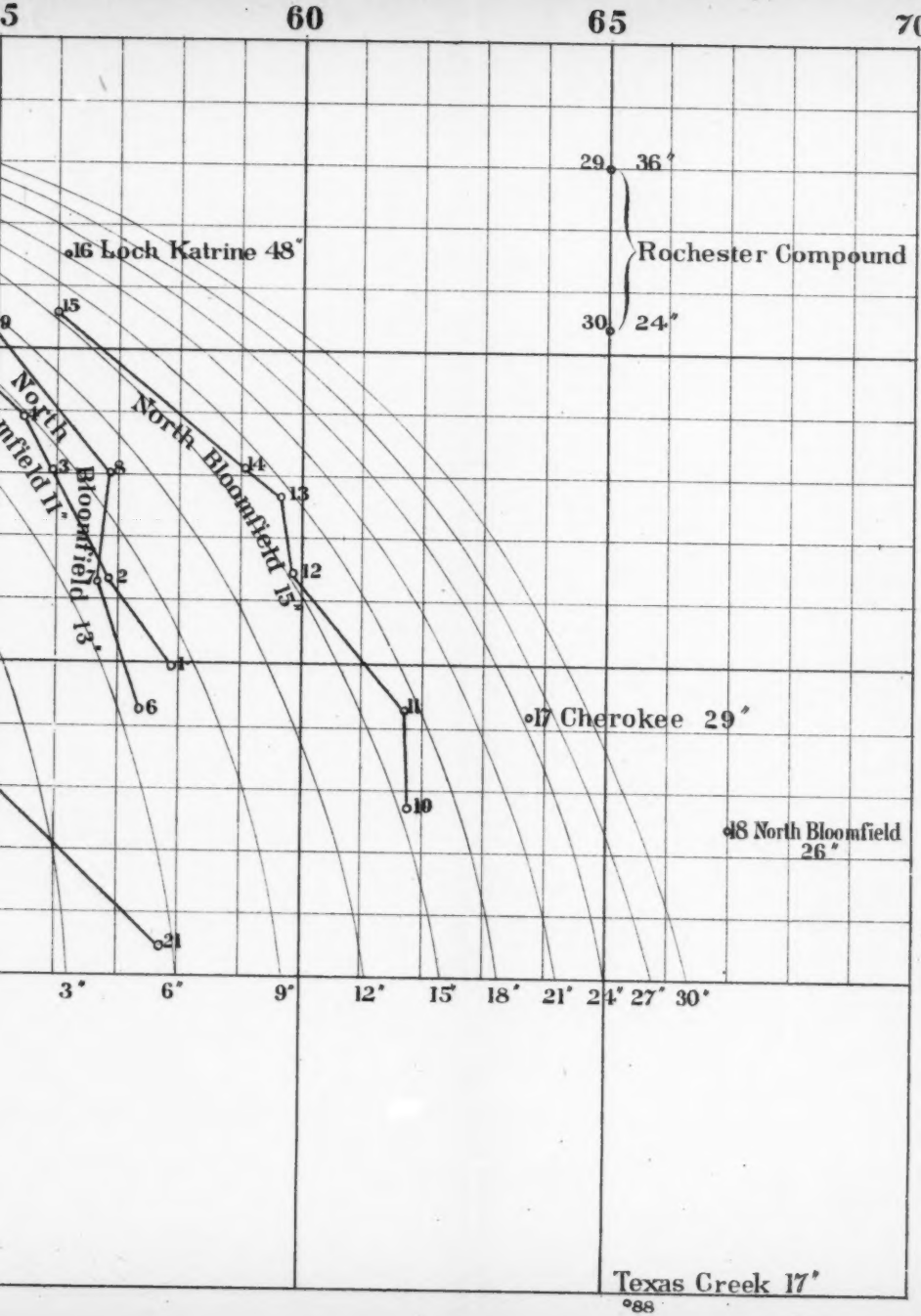


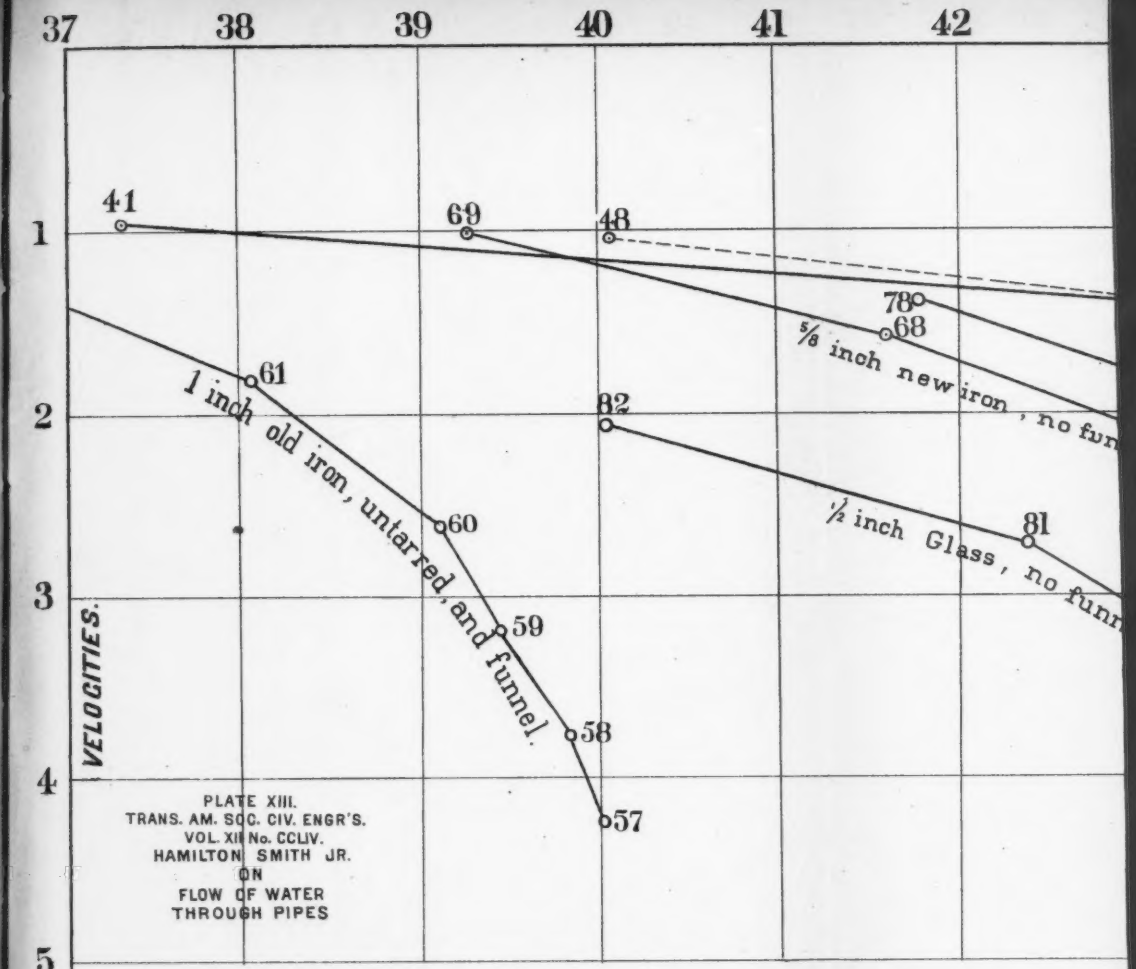
A

CIRCULAR PIPES

$a\ V = m \left(\frac{d h^1}{l}\right)^{1/2}$

glish feet.

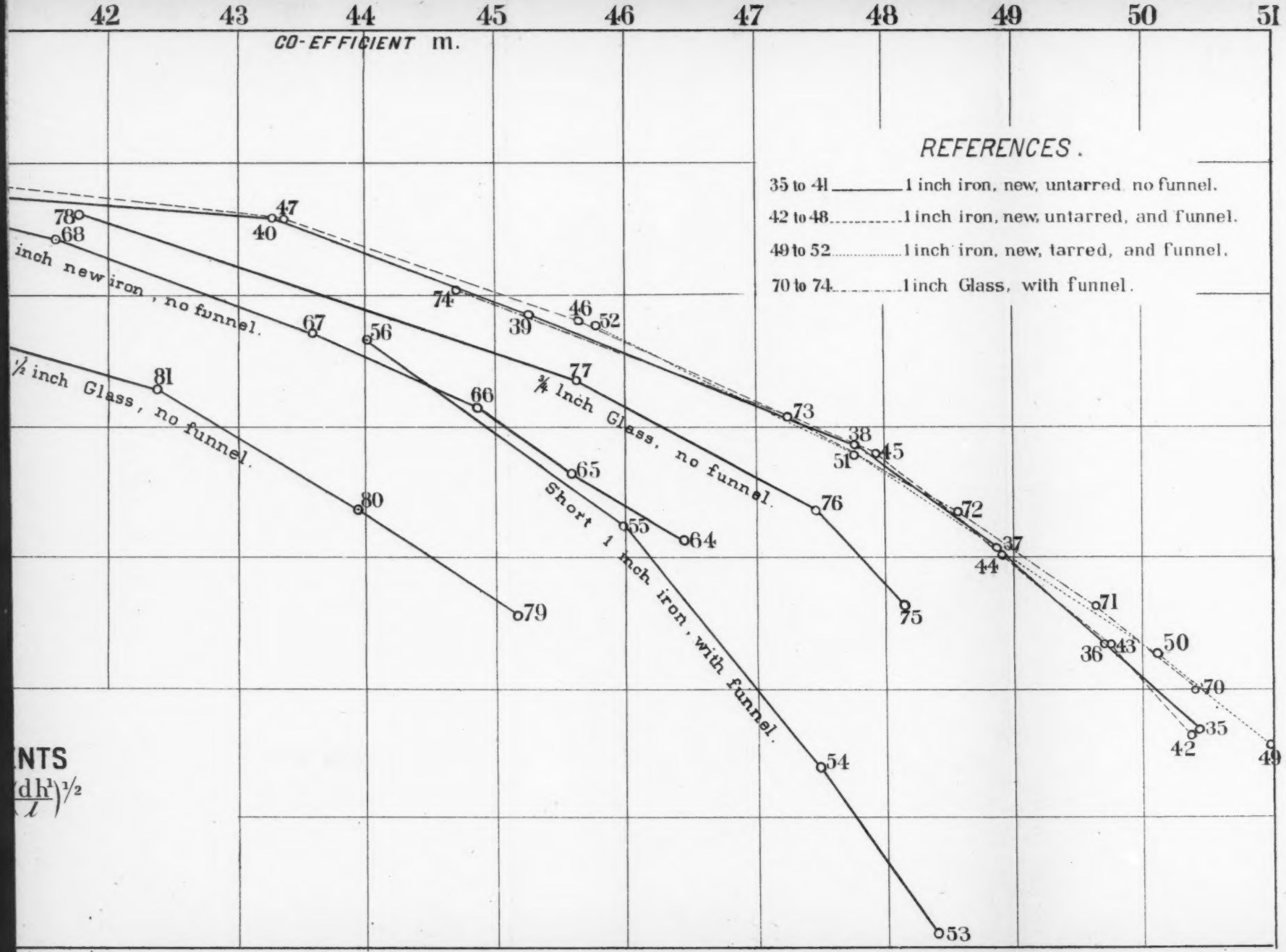

5
60
65
70
29
36"
Rochester Compound
30
24"
16 Loch Katrine 48"
15
North Bloomfield 15"
North Bloomfield 13"
mfield 11"
14
13
12
11
17 Cherokee 29"
10
18 North Bloomfield
26"
21
3"
6"
9"
12"
15"
18"
21"
24"
27"
30"
Texas Creek 17"
88



Sheet B

NEW ALMADEN EXPERIMENTS

Reduced to formula $V = m \left(\frac{dh^1}{l}\right)^{1/2}$


42
43
44
45
46
47
48
49
50
51
CO-EFFICIENT m.
REFERENCES.
35 to 41 ——— 1 inch iron, new, untarred no funnel.
42 to 48 ..... 1 inch iron, new, untarred, and funnel.
49 to 52 ..... 1 inch iron, new, tarred, and funnel.
70 to 74 ..... 1 inch Glass, with funnel.
inch new iron, no funnel.
½ inch Glass, no funnel.
¾ inch Glass, no funnel.
Short 1 inch iron, with funnel.
78
68
47
40
74
39
46
52
67
56
77
81
66
73
38
51
45
65
80
55
64
76
72
37
44
75
79
71
36
43
50
70
35
42
49
54
53
NTS
$\frac{(dh^1}{l})^{1/2}$

The standard of measure used was that of the United States Coast Survey.

The temperature of the water in Nos. 35 to 87 was about 65° Fahr. In the other experiments, from 50° to 55° Fahr.

The writer here desires to express his obligations to the North Bloomfield Gravel Mining Company, and to Mr. J. B. Randol, manager of the Quicksilver Company, for the facilities afforded by them in pursuing these investigations.

These 88 experiments have all been reduced to the simple formula:

$$v = m\left(\frac{dh'}{l}\right)^{\frac{1}{2}}$$

Where v = velocity in English feet per second.

d = mean diameter.

l = length.

h' = effective head.

m = variable co-efficient.

This is identical with the usual form:

$$v = n\ (rs)^{\frac{1}{2}};\ 2\ m = n.$$

The effective head h' was derived from the total head h, as follows, c being co-efficient of contraction at entrance:

$$h - h' = \frac{v^2}{2\ gc^2}.$$

The comparative results of these experiments are best shown by the following graphic delineations, the co-efficients m being used as abscissæ, and the velocities in feet per second as ordinates.

Sheet A shows that the value of m varies with:

First.—The character of the interior or wetted surface, being very low with small, rough pipes.

Second.—It increases with the velocity with smooth pipes, but this increase is slight with small rough pipes.

Third.—It increases with the diameter, which is to some extent a sequence of the first proposition.

It may be observed, in connection with the second proposition, that the co-efficient m will be infinitesimal, with an infinitesimal velocity. In fact, with a minutely appreciable head, m will probably still remain infinitesimal, owing to the viscosity of the water.

The value of m at first increases very rapidly with the increase in velocity ; this increment gradually diminishes until, with high velocities, m becomes nearly constant.

Mr. I. T. Fanning, in his "Treatise on Water Supply Engineering," arrives at the same three general conclusions as those here given.

On sheet A, Plate XII., are drawn curved lines representing different diameters from ½ inch to 30 inches. The intersection of these curves and the horizontal velocity lines are intended to show the varying values of m—the vertical lines—as indicated by those 88 experiments, for smooth pipes, and with velocities ranging from 1 foot to 15 feet per second.

The data for the 1-inch and 15-inch curves seem to be fairly complete. The curves between the diameters have been interpolated ; those from 18 to 30 inches have been added by analogy. Experiments Nos. 18, 29, 30 and 88 seem to show that for these larger diameters the value of m is placed too low.

As the smoothness of surface is such an important factor in diameters of less than 30 inches, and as in ordinary practice there are such wide differences in this respect, any diagram or formula must be modified by the constructing engineer to suit the varying conditions of the problem.

On Sheet B, Plate XIII., are plotted on a much larger scale most of the new Almaden experiments, for the purpose of more accurate comparison.

It will be observed, upon inspection, that 35-41 and 42-48 form identical curves ; after the same pipe was coated—49 to 52—the value of m was slightly increased for velocities above 4 feet, although the diameter was a trifle diminished by the coating. The glass pipe of .0764′ diameter shows the same value of m as the iron-coated (tarred) pipe of .0873′ diameter.

The accuracy of the new Almaden experiments is verified by the regularity shown by plotting their results. This is not surprising, as, owing to the small quantity of water handled, it was comparatively easy to measure it with much accuracy.

In the larger pipes, one of which discharged 50 cubic feet per second, it was not practicable to measure the water directly, on account of the large outlay which would have been requisite to build measuring tanks.

Any indirect measurements of flowing water, either over weirs or through standard apertures, are always unsatisfactory, as the slightest change in the conditions will affect the accuracy of the results.

A discordance, however, is to be noted in these experiments (35 to 87), which is the low value of m in the pipe 16⅔ feet long, when compared with its value in the pipe 60 feet long (49 to 52) of the same diameter.

This discordance leads to the belief that the usual correction for loss of head due to imparting velocity to the water $\left(\text{loss of such head} = \frac{v^2}{2g}\right)$ should be modified. The discrepancy can hardly be caused by the deduction for contraction at the orifice, as Experiments 35 to 41, and 42 to 48, give practically identical curves, and where first a considerable correction was given for the contraction, and afterwards with the same pipe, a very slight correction for the same cause.

An extended series of experiments with pipes of the same size, but of widely differing lengths, made with proper care, is much to be desired, in order to definitely settle this point.

It may be remarked that some 150 additional experiments, made by standard authorities, have been carefully tabulated for purposes of comparison with the 88 here given. They were not used in preparing the curved lines on the diagram, as their results were often contradictory, although generally confirming the correctness of the three general propositions before stated.

The importance to the hydraulic engineer of this question is best appreciated by the statement that the experiments given show a variation in the value of m from 33 to 67.

The first 87 had been tabulated by the writer before he designed and built the Texas Creek pipe—No. 88. The expected value of m for this siphon was then fixed at 66.5, this value being deduced from the preceding tests. The trial test of this pipe showed a value of 65.56, which, as stated before, is probably slightly less than its real value.

No attempt has been made to prepare a formula which would meet the many varying conditions of this problem. Any such formula would necessarily be complicated and inconvenient for general use.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCLV.
(Vol. XII.—April, 1883.)

DISCUSSION.

AT THE ANNUAL MEETING, JANUARY 17TH, 1883.

ON THE INCREASED EFFICIENCY OF RAILWAYS FOR THE TRANSPORTATION OF FREIGHT.

PAPER CCXLVIII.,

By WILLIAM P. SHINN, M. Am. Soc. C. E.*

DISCUSSION

By JOHN B. JERVIS, CHARLES PAINE, E. P. VINING, JOSEPH S. PAXSON, J. GARDNER SANDERSON, CHARLES E. EMERY, O. CHANUTE, CHARLES H. FISHER, H. BISSELL, M. N. FORNEY, THEODORE COOPER, WILLIAM P. SHINN, AND ROBERT L. HARRIS.

JOHN B. JERVIS, Hon. M. Am. Soc. C. E. (by letter to the Secretary).—I thank you for an advance copy of Transactions of the Society, containing the paper of Wm. P. Shinn, Esq., M. Am. Soc. C. E. I have read the paper of Mr. Shinn with much interest. It is the work of a man who has profoundly studied the subject of an important public

* Transactions, Am. Soc. C. E., Vol. XI., p. 365, November, 1882.

interest, and I regard it as a credit to the Society, and of great value to all, especially railway proprietors.

Mr. Shinn must have devoted great labor in gathering the very valuable statistics he has presented. They in themselves show the vast progress of railway interests.

Few at the present day can appreciate either the original difficulties in this comparatively new method of transport, nor the great stride that has been made in its efficiency. It has, no doubt, been one of the most important factors in the great national progress of our country and of the civilized world.

The great thing for the Society to consider is, the particulars on which Mr. Shinn relies to support the argument of his paper.

The paper claims increased efficiency and, of course, economy in railway freights.

The first item relates to improved road-bed and rails. These should always go together, as a poor road-bed will not be made good by merely a good rail. We commenced building railways when we had little money, and adopted the iron rail before we made corresponding improvements in road-bed. The road-bed was improved but slowly, but it did improve, and would have made greater progress had not financial considerations prevented. Though the early railways were much inferior to what they should be, and what they now are, their value in transportation was then so obvious, that everywhere men were anxious to have them, and made constant effort to find means for their construction.

The road-bed was the most neglected part in the early railways. It was considered an iron rail would make all good. The necessity of thorough drainage, on which a bed of hard and porous materials could maintain uniform support for the rails, has only grown with the experience that developed its necessity. Great improvement has been made in this feature, but it needs much further improvement before we can say our railway beds are complete. An important defect in construction has often arisen from efforts to cheapen cost by laying the bed too low to admit proper drainage, and this has only been partially remedied. In many places the bed must be still more lifted in order to secure efficient drainage for a good road-bed.

Next to the bed comes the rail. In regard to the superiority of steel, as compared with iron rails, I have not the statistics necessary to form a confident opinion. As Mr. Shinn very justly observes, this must be de-

termined, not by the time in use, but by the weight of traffic they carry. This is apt to vary so much, that great care in collecting statistics is quite necessary to any accurate determination of the question. In the early days of railways it was quite common for iron rails to carry double the traffic of those subsequently used, and at the time steel was introduced our iron rails were poor, and did not economically bear the weight put upon them. Steel rails were therefore introduced at a favorable juncture. But as they were about double the cost of iron, they came into use very slowly, and with light section. The latter evil was remedied when the cost per ton of steel became about the same as iron, and now the weight of steel is a less objection than formerly, or none at all, as compared with iron.

It is obvious, the increased weight a steel rail will carry economically depends on the firmness and uniformity of the road-bed. I presume the latter has been improved since the introduction of steel. The road-beds for iron rails were never adequate to sustain properly the iron rail, and were in course of improvement when steel was introduced. No doubt the road-beds have been more improved for steel rails. So, the utility of any rail depends much on the road-bed. I therefore consider the question of rail as closely connected with road-bed.

In his estimate of the superiority of steel, I presume Mr. Shinn has considered it in connection with corresponding improvement in road-bed ; still I think his estimate of economy is rather large, though it has no doubt greatly increased railway efficiency.

The improvement noticed by Mr. Shinn in increase of double track and sidings is obvious. A single track railway will do a large business, but its increase of traffic will necessitate a double track on the basis of economy. In any case there is great importance in the arrangement of terminal side tracks. In early days this was not fully appreciated. Experience, with much study, was needed to arrange a system of terminal side tracks. No doubt great improvement has been made, and more is needed. It requires careful study, with experience, to arrange a system of terminal side tracks for the most convenient operation.

A point of much importance, as noted by Mr. Shinn, is the relation of load and empty weight of freight cars. The case he shows is very striking. An increase in the weight of car of 1 500 pounds, or three-quarters of a ton, being found sufficient for a 10-ton increase of paying load, is very important. I have long been of the opinion that the old

10-ton cars were much heavier than necessary. I therefore readily appreciate this benefit, which is very obvious when it is considered that all unnecessary weight of car involves the carrying of so much load for nothing.

No doubt improvement has been made in administration, but it seems Mr. Shinn does not show that this has been true in all cases. The signaling is no doubt a benefit both in regard to safety and efficiency, and is a very important matter.

The capacity of administering the service of cars does not appear to have been an improvement. No fault of the cars if they are unnecessarily left on side tracks. This proves a no small delinquency in management, and will be corrected when railway managers find this portion of their cars do not pay.

Mr. Shinn has searched out and presented his claim to increased efficiency, and has afforded to railway managers very important suggestions for managing their property. A very valuable feature of Mr. Shinn's paper is its showing of the necessity of skill in conducting railway operations. Some of the operations are very simple, but for the most part require large experience and careful thought.

While I think Mr. Shinn has ably made out his case of increased facilities of railways, I will suggest one point he seems to have omitted. In this I have no desire to impair any improvement he has presented. I refer to the tractile power of a locomotive on a railway. In about 1824 it was scientifically set forth that the tractile power of adhesion was $\frac{1}{25}$ the insistent weight on the rail. In this view of the question, the Liverpool and Manchester Railway, in England, was nsidered to require stationary machinery to move on a grade of about 50 feet to the mile. This looks singular at this day. It was a question that called a council of engineers to examine and report upon it, after projects had been made for stationary engines. This council decided, after a labored investigation, to recommend the stationary engines. Mr. Stephenson, the engineer of the railway, had more faith in adhesion, and was so persistent that the managers finally yielded. It was soon demonstrated that adhesion could be relied on at a higher ratio. In 1828, in presenting my report on the Carbondale Railway, I ventured to take the adhesion at $\frac{1}{17}$, which then appeared as large as could be justified. In my report on the Hudson River Railway in 1846, I assumed the adhesion at $\frac{1}{8}$, a great advance, that seemed justified by the experience at that time. Now I suppose it

would not be taken at less than $\frac{1}{7}$, or five times greater than in 1824. This has been a gain growing steadily for near 50 years. It was well known that friction of iron on iron was about $\frac{1}{6}$, but it was supposed that the rain, frost and fine mud would so impair this that it could only be relied on in all conditions of the rail to meet the rate of $\frac{1}{25}$. This principle of adhesion, that started so timidly in 1824, has been so gradually and almost imperceptibly advanced, as to show a five-fold increase in its useful power. In fact I know of no means of tractile efficiency that is equal to steam power applied by adhesion to the rail.

If anything more was needed to confirm Mr. Shinn's position of improved efficiency in railway transport, it is easy to find it in general results. A few years since it was confidently considered by the friends of the Erie Canal, of New York, that the canal would be fully able to sustain its freight traffic as against railway competition. But as time moved on it was found necessary to reduce canal tolls. This was done year after year, the tolls became very small, and, as we now see, they are wholly removed, the State to make repairs and sustain all other expenses for maintenance, making the canal free of tolls. In fact, the canal pays nothing for its cost or maintenance. This fact speaks volumes for the power of railways as a superior means of transport. It has been growing for 50 years, and it is now a question if the free Erie Canal, worked by the old method of animal power, will do more than maintain a bare existence.

It is now clear that if the canal is to be made an important channel of transport, it must use locomotive steam engines, moving on rails. There is no propeller that can equal locomotives, as above, in economy of traction.

With the foregoing general remarks, I close my notice of a paper that fully speaks for itself in ably illustrating an important subject.

Charles Paine, M. Am. Soc. C. E.—No person can read Mr. Shinn's admirable paper without instruction, and by those interested in railroad management it will be found full of valuable suggestions.

In reference to detention of cars at stations and private sidings, he advises a low rate of demurrage as the remedy for the difficulty; and it may be of use for me to add that this experiment has been often tried, and, so far as I have been able to learn, with entire success, whenever the penalty has been regularly and persistently exacted.

The habits of men of business are all opposed to the payment of

any sum, however small, in consequence of delays which by promptness and proper arrangements beforehand could have been avoided. I have no doubt that a penalty of twenty cents per day for the detention of a car would prove very effectual; fifty cents per day has, within my own experience, sufficed to prevent improper delays to cars where carelessness and indifference about unloading had been the rule. But this penalty will not—I might almost say cannot—be enforced by the freight department as it is generally organized upon American railroads; some other department—as the superintendent's, for instance—must be entrusted with its enforcement. Our freight departments are constructed with a view to obtaining the largest amount of freight, and will do nothing, willingly, which will seem to require the shipper or consignee to conform to any rule as to time of unloading, for fear that some other road may not require it.

Mr. Shinn again hits the nail on the head in citing the detention of cars on foreign roads as one of the great evils of our railway system; it is probably the one for which it is most difficult to provide a remedy. For I cannot agree with Mr. Shinn that the *per diem charge for cars when on foreign roads* would be a success. In fact, it was once agreed upon and tried on some of the lines between Chicago and New England, but only for a few weeks, when its impracticability was demonstrated. The reason is this: the terminal road acts only as the agent of all the other roads forming the line; the most western road shipping to New England is just as anxious to have a chance to get its freight to destination as the little terminal road is to do its share of the business; and while the terminal road will undertake to do the best that it can for its western ally, it had better not receive the western cars than to be responsible for a per diem charge. A snow-storm or a flood, or many other things, may so damage affairs at the terminus that it would be impossible to get the cars promptly unloaded—yet, under the per diem arrangement, the short road at the eastern end of the route would be required to pay much more in penalties than it had ever received for doing the business.

Another obstacle to the collection of a per diem charge exists in the variable demand for cars. During the fall and winter seasons shipments from the west are active; every car is called into requisition; but no western road could afford to say to the blockaded eastern roads, we will not let you have our cars unless you pay a per diem charge for their use.

The eastern roads would reply: our yards are everywhere full of cars; keep yours until we get those we have unloaded. The western road sees how it is, and prays for mercy's sake do the best you can for us; take a fair share of our cars through for us, or we will have no business; we will not charge you anything but usual mileage.

In midsummer there is little freight moving eastward; cars begin to accumulate to an uncomfortable extent on the sidings of the western roads; they receive them at considerable inconvenience to have them ready against the commencement of the fall shipments, but they would not do so if responsible for a per diem charge.

The remedy for improper delays on foreign roads seems to me to be attainable more readily through a clearing house to which all roads shall report, and which should have authority to order the movement of cars which are not detained for good cause. By notifying the road whose cars are so detained, as well as the managers of the roads on which the cars are—perhaps unknown to themselves—so detained, much could be done to improve the movement of cars.

Mr. E. P. VINING, Freight Traffic Manager Union Pacific Railway Company (by letter).—I have been very much interested in your paper, "On the Increased Efficiency of Railways for the Transportation of Freight," which was read upon the 20th ult. before the American Society of Civil Engineers. While I appreciate that portion of it which relates to the increased efficiency that has been secured during the last few years, I believe that the attention which you direct to the weak points in the present system—or rather lack of system—for handling freight upon our American railroads will prove of even greater practical importance, and hope that your paper will be an important factor in bringing about those changes which must be made before our roads will be capable of handling promptly and cheaply the increased volume of business which there is reason to hope that the future will bring them. The growth of our railway system has been a matter of such little time that our railroad officers have scarcely had the time necessary to abandon the crude methods originally adopted for short lines with a small local business, and substitute for them a thorough system adapted to the prompt and rapid transportation of an immense tonnage over great distances.

There is no reason why freight left at a depot at New York for transportation to Chicago should not reach Chicago and be ready for delivery

at some fixed hour, with the same reliability and certainty that exist regarding the hour at which a passenger from New York will reach his destination.

There is no sufficient reason for the uncertainty that all business men have as to the time when their goods will reach them.

The demand for greater speed than is now made is not half as pressing as the demand for greater reliability and certainty; but the average time that is now taken for freight transportation can be and will ultimately be greatly diminished.

Freight from New York for Council Bluffs, if moved at a constant average speed of only ten miles per hour, should reach its destination in six days.

As a matter of fact, such freight seldom arrives in less than nine days; the average time is not less than two weeks, and three weeks is not an unusual length of time for such freight to be in transit.

It is curious to observe that at just the times when the demand for transportation is the most active the movement of freight becomes the slowest. At a time when business is light, freight will arrive at Council Bluffs from New York, with tolerable regularity, in about fourteen to sixteen days; but if the amount of freight offered for transportation is suddenly increased, instead of meeting this increased demand for cars by moving the cars more promptly and rapidly, it seems to be a question as to whether the cars that have been loaded shall ever be moved to their destination at all; the mileage per day of the cars upon the various roads being run down to only about one-half of the usual average.

Then, as you say, the cry resounds from all quarters for "more cars," when the fact is that the side tracks and yards are lumbered up with more cars than the engines and men seem able to handle; and the cars already upon the road would be capable of doing double the amount of business if they were only loaded, hauled and unloaded promptly.

It certainly should not be difficult to make an average of fifty miles per day with railroad cars. At a speed of sixteen miles per hour, this would keep the cars in motion only three hours per day, and allow them to stand idle twenty-one; or, to put the matter in another shape, only one-eighth of the cars upon the line would, upon an average, be in motion, while seven-eighths of the cars would be standing upon side tracks.

Nevertheless, it is true that upon many roads which do not make that average mileage a constant demand for "more cars" may be heard.

It seems a simple matter that trains should be made up exclusively of through freight; that the engines should start with no greater number of cars than can be taken through without breaking up the train; that the train should have a schedule time, and should make it; that upon arrival at the destination the cars should be unloaded within twenty-four hours, and within another twenty-four hours either reloaded or—in case there is no return freight for them, and there is a demand for the cars at the other end of the line—that they be started back empty, and within a reasonable length of time reach the point from which they originally started.

Simple as all this seems, and easy as it should be under a proper system of management, it is not done.

That it will be done, and at no very distant date, I hope and believe.

Mr. JOSEPH S. PAXSON (by letter).—I have noticed in the last number of the *Scientific American* a short report of your essay on the "Increased Efficiency of Railways for the Transportation of Freight," read recently before the American Society of Civil Engineers, and that the subject will come up January 17th for discussion by the Society at its Annual Meeting. Communications on the subjects to be discussed were invited.

One method for "increasing the efficiency of railroads" appears not to have been thought of, or at least was not enumerated in the list reported for discussion, and that is, the use of axles with loose or independent wheels, by which not only curve resistances, but the wear of wheels and track, are reduced to a minimum on tangents as well as on curves.

In a recent number of *Forney's Railway Gazette* appeared a table of curve and grade resistances, from which I quote the following, which, if you have not already seen, may be of interest to you:

A 36-ton engine, having 4 drivers, with 12 000 lbs. on each, will haul at 20 miles an hour, in addition to the weight of engine and tank, on a straight level track, cars all fitted with rigid wheels, 1 096 tons of 2 000 lbs.

On a level 5-degree curve it will haul 921 tons.

Loss due to a 5-degree curve, 175 tons.

The same engine will haul on a 10-degree level curve, 662 tons.

Loss due to a 10-degree curve, 464 tons.

The capacity of an engine is limited by the sharpest curve and the highest grade on its route.

Now, if axles with independent wheels will effect a saving of, say, one-half the above losses—and I think much more than that may be saved by their use—will not the efficiency of railroads be very materially increased thereby?

It only remains for me to apologize for thus addressing you, while I excuse myself for so doing on the plea of my desire to call your attention to this subject, which I consider an important item in the discussion of "Increased Efficiency," which I feared had been overlooked or passed by.

J. GARDNER SANDERSON, M. Am. Soc. C. E.—There is one point in Mr. Shinn's paper I desire to call attention to. Mr. Shinn very properly asserts that "the increased movement of cars will require *more trains*, which will make it necessary for trains to follow more closely," and he says, "What is wanted is a good automatic signal system, whereby short 'blocks,' operated by the trains themselves, may be used for freight trains; keeping them at least one mile apart when running at full speed." As I have been somewhat identified with the introduction of signals on railroads, I simply wanted to say, that such automatic signals exist, and have been in use for several years on some of our roads, in the East especially. And there is no question at all about their efficiency in facilitating traffic. On the Fitchburg road, of Massachusetts, where they have been used now for four years or more, it is shown that they can run trains in succession with greater safety by signals than they could by time tables. Testimony to that effect has been given by the superintendent of that road. The same is true of the Old Colony and the Eastern roads. The Pennsylvania road employs the system, and have subdivided many of their blocks, where the blocks are five miles or more apart, by introducing these automatic signals perhaps a mile or less apart. In that way their trains can follow in rapid succession, not being obliged to depend upon uncertain elements of time. The time signals have been demonstrated to be worse than useless.

Then, in the matter of interlocking switches and signals, referred to by Mr. Shinn, they are being rapidly introduced in this country now; perhaps they are more developed on the other side than here, but the roads generally throughout the country are adopting the system of inter-

locking their switches with signals, so that it is almost impossible for trains to either collide or run into an open switch, unless by disregarding the danger signals. I should suppose these elements, in estimating the cost of traffic, would be very important. If we take the immense number of accidents that happen from collisions and open switches, the destruction of rolling stock and destruction of freight, it certainly would constitute a very important element. I believe the Railroad Commissioners of Massachusetts in their recent report place the average damages that eight railroads entering Boston have paid in ten years at $120 000 annually, and that not including the destruction of freight.

Then there is the point of detention at crossings. That subject is being developed. I think it was mentioned that the Ohio Railroad Commission of the Legislature made a rule exempting railroads from these know-nothing crossings where they are protected by an adequate system of signals; and the Railroad Commissioners of Massachusetts have adopted the same course.

I only refer to this subject as Mr. Shinn had mentioned "what was wanted." I think that the thing wanted is at hand, and that it is being gradually adopted by railroads generally.

One other point, mentioned in one of the letters read by the Secretary, and that is that the locomotive was the most economical motive power now known for the transportation of freight. It is not long since it was considered that coal carried over the mountains of Pennsylvania was carried cheaper by their gravity road or incline planes than in any other way. Quite recently I understood the superintendent of the Pennsylvania Coal Company to say that they could carry coal cheaper to the top of the mountain with a locomotive than they could with incline planes. I mention this as confirming what was stated in the letter.

CHARLES E. EMERY, M. Am. Soc. C. E.—As no one appears at the present moment to wish to discuss directly the paper under consideration, I will offer a few points suggested by the discussion of Mr. Jervis, which has been read this evening. Mr. Jervis, referring to the much greater efficiency of locomotives of recent construction, particularly calls attention to the increase of adhesion now known to be available compared with that allowed for and attained in earlier locomotive practice. Of course, the co-efficient of friction has not changed, although the efficiency has been increased; and if we study why this is so we may learn to remedy some defects existing even at the present day. We

obtain a greater proportion of the weight on drivers as tractive force simply because the operating forces and weight on drivers are better co-ordinated together. The weight is such that a pressure in cylinders of a given size can barely slip the wheels, and the boiler power is sufficient to keep up this condition continuously. This is true independent of mere increase of size, which increases everything proportionately. Well as this is understood by all experts, there are blunderers to this day who persist in increasing the size of the cylinders out of proportion to the weight or boiler power, or both, making an engine difficult to start and run without glossing and wearing out the tires, and at high speeds running down the steam pressure, etc. All do not see that these considerations call for smaller cylinders, larger drivers and more boiler power for passenger than for freight engines, and very few know that one of the first two alternatives is as important as the third, for the reason that locomotives at high speeds of revolution have less adhesion than at lower speeds, on account, principally, of the lifting action of the counter balances, but also to the vertical vibration due to the inequalities of road-bed. To secure economy, the steam is necessarily worked expansively, which causes, instead of a steady pull, a pulsating tractive force, which with large cylinders is felt throughout the train, causing nervousness, frequently attributed to the joint action of the road-bed and car-springs, but readily detected by watching a pendulous object. The effect of over-large cylinders for freight engines is observed by the repeated slipping on a grade, although some locomotive engineers will do much better than others. A little thought shows best how to overcome the difficulty. Economy is of no consequence; the pulsating tractive force due to expansion starts slipping at some part of the revolution. The problem is to get a steady pull as strong as possible, keep it up and not get "stalled." Attempting partially the vernacular of 29 years ago, when, out of school hours, I explained the formula and drawings in D. K. Clark's original work to a progressive locomotive engineer, and mounted the footboard on Saturdays for practical work, I may say to those here present whose engineers stall on the grades, that the best way to get out is to "hook clear forward," run the steam down as low as she will "hold her water," set the throttle fairly well open and let it alone, when, if the engine steams as she should under such circumstances, the pressure may be kept at precisely what she will stand, without slipping, by regulating with the furnace door—that is, keeping steam down by admitting cold

air. If your man keeps cool and everything steady, he will take a train that will surprise the ones who work themselves to death opening and shutting the throttle. A few hundred pounds of coal extra on the grates and foot-board will help the extra car or two up remarkably, operating on the same principle that ash-pans 2 inches thick and foot-boards, &c., 3 inches thick, of cast-iron, do on the Boston and Albany Railroad. I close, trusting this has been of interest during a lull in the debate, though I have to connect with Mr. Shinn's main track through the partial diversion of Mr. Jervis' shunt.

The CHAIR (Vice-President WILLIAM H. PAINE).—Will Mr. Chanute continue the discussion of the paper?

O. CHANUTE, M. Am. Soc. C. E.—I regret very much that I have so occupied my time with other engagements that I have been utterly unable to prepare myself on this subject. I have been even unable to read Mr. Shinn's very interesting paper since it has been published, though I have seen the advance proof-sheets; therefore, to my regret, I shall not be able to contribute at present anything to the discussion, which I hope will fully cover all the important points raised by Mr. Shinn.

CHARLES H. FISHER, M. Am. Soc. C. E.—Like Mr. Chanute, I have had other engagements to such an extent within the last two weeks and since the publication of Mr. Shinn's paper that I can hardly say that I have more than read it; but it presents subjects of very deep consideration to those who are connected with the operation of railroads. I do not propose now to attempt to discuss it, but merely to mention one fact in my own experience as bearing upon this question of reducing the cost of operating railroads. During the past year the company with which I am connected has been engaged in improving a difficult portion of its lines through the City of Rochester. We had, from the crossing of the Genesee River and our station, which was directly west of it, an ascending grade about 1 200 feet long, and at the rate of 115 feet to the mile; going east from the river bridge we had an ascending grade of 2 000 feet in length and about 53 feet to the mile. Our eastern-bound trains would generally surmount that grade, but with our western-bound trains, in order to get them up the short grade, we were compelled to use heavy helping engines, and had three in service.

The difficulties in operating our road, crossing the street that it did, and the obstruction that it caused to ordinary traffic, made the people of

the City of Rochester restive, and improvement was asked for. After some negotiations and some legislation, a contract was made between the representatives of the city and the company, by which a plan for changing the grade was adopted, and the work has been in progress since March last. Of the entire 2 miles which was to be changed, we are now using on the elevated grade all but about 2 000 feet in length, although a portion of this present elevated part is temporary. Instead of the three engines that were used for helping before this improvement was advanced to its present condition, we are now using one, which runs up a short temporary incline at the east end, and runs back on the same track, the entire distance run by it being about 1 200 feet. Our trains eastward-bound have no difficulty whatever, and those westward are assisted only at this one point. Before the work was decided upon, an estimate of the saving from this improvement was made, and it was much to my surprise to find that with the business we were then doing it was easy to expect a saving of $70 000 a year in the cost of operating the road from making this improvement. The results thus far attained indicate that we shall do as well as that—perhaps better—and they demonstrate that reduction of ruling grade is an important step in diminishing the cost of transportation.

The question of increasing the power of our engines has recently been presented to me for consideration, and I have been asked to estimate the wear upon the rails caused by the ordinary 8-wheel engine with a certain load upon each driver, in comparison with that produced by a 10-wheel engine with the same load upon each driver, and thus aggregating 50 per cent. more driven load. My reply was that I could only see an additional wear from the pressure of the extra pair of drivers. There was evidently additional wear upon the rail, but how to measure it I was unable to suggest. And I mention it now, hoping that some gentleman may tell me if there is anything more than that. There would be additional friction in passing around curves, and with the long wheel base of the 10-wheel engines there would necessarily be some lateral slipping, but I can see no more actual wear to the rail than that coming from the rolling friction of the extra pair of drivers. The question was asked me, "Do you mean to say that there is no more wear to the rail with a train of 35 cars drawn by an 8-wheel engine slipping all the way than with one of 35 cars drawn by a 10-wheel engine, and not slipping?" I said, "I do not say anything of the kind." It was in my mind that

if there was any slipping at all, the 8-wheel engine was over-loaded with the 35 cars. There is one point in connection with this that I think railroad managers hardly appreciate. Seven or eight years ago trains were adapted to the engines then in use. They hauled a certain number of cars for a train load—possibly 40 or 45. In the meantime it has been found economical to increase the strength of the car and to give it greater capacity, and now they are made to carry 20 tons instead of 10 tons, and yet it seems that the managers of railroads expect that the trains will consist of as many cars as before. That is one reason why we cannot move as many cars with the same engine as was done years ago. And yet it seems to be lost sight of.

I am of opinion that the efficiency of railroads would be increased in many cases by a slight expenditure in reducing their grades at certain points. I know that on one division of our road, where we now have grades of 30 feet to the mile to overcome, we can reduce to 20 by revising perhaps 11 miles, mostly light work, and I think that engineers connected with roads in operation who desire to improve them, should give their attention to this point of reducing grades.

The Chair (Vice-President William H. Paine).—Mr. Fisher has asked some pertinent questions. Perhaps some others may be able to answer.

Charles H. Fisher.—I would like very much to hear some explanation on that one point—what the relative wear or effect on the rail is from the two classes of engines, assuming the same load on each driver in both cases, the one engine having 4 and the other 6 drivers.

H. Bissell, M. Am. Soc. C. E.—There is one very serious objection to the suggestion of Mr. Shinn, that engines should be run first in first out, and that is in regard to the changing of engineers. You cannot lay the blame for want of care of the engine to the parties who run them. If you put one man on an engine and keep him there, you know whether he keeps his engine right or not, but when you shift your men you do not.

Charles H. Fisher.—I would say in regard to the working of engine crews on the New York Central and Hudson River Railroad, that we have two crews to an engine, but they are not changed from engine to engine ordinarily, so that we fix the responsibility for any difficulty with the engine on one or two men.

Charles E. Emery.—Mr. Fisher has suggested an interesting ques-

tion as to whether it would be economical for other reasons to use three pairs of drivers instead of two. The economy of one less crew is well understood, and the long train takes fewer men. The question then arises, what he would settle as the length of the train on the New York Central Railroad to be safe. I suppose the difficulty there in using the large engine is that the train would be so long it could not be handled in case of accident. Just what his conclusion is, and on what their practice is based, I think would be interesting here.

The CHAIR.—That is an important question.

CHARLES E. EMERY.—Whether the 8-wheel engines are powerful enough to handle the trains that can be best managed? If you had longer trains and larger engines could you do it safely?

CHARLES H. FISHER.—That is just the important question—how many cars should constitute a train?

M. N. FORNEY, M. Am. Soc. C. E.—I should like very much to have Mr. Chanute's opinion on that subject, as he has had probably as much experience in the handling of long trains and the use of consolidation engines as any other man in the country. I believe, so far as my observation goes, and the information I have received in intercourse with railroad men, that all who have tried the use of very powerful engines in the running of long trains have come to the conclusion that the difficulty of handling long trains is a *superstition*, and that it requires only a little experience to be able to handle a train of any length which have thus far been tried on any of the roads. In regard to Mr. Fisher's conundrum about the relative wear of rails with a 10-wheel engine and an 8-wheel engine, the case seems to be very plain. If you have a 10-wheel engine with 6 drivers, each wheel of which has as much weight as each wheel of an 8-wheel engine, you, of course, ought to draw 50 per cent. more cars. In other words, you would have to run two 10-wheel engines over a road to do the same work you could do with three 8-wheel engines. Now, it is improbable that there would be any difference in the wear of rails from running on those six pairs of driving wheels over a road in sets of three pairs each, or from what there would be if run in sets of four pairs each. Of course, there is some slight difference in regard to the wheel base. That of the 10-wheel engine is usually longer than that of the 8-wheel engine. But where the gauge of the track is as it should be, and the curves are proper, and the gauge of the wheels is right, there is no difficulty from the length of wheel base. I should like to ask Mr. Chanute

whether on the Erie Road they have any difficulty in handling as long trains as their consolidation engines will draw.

O. CHANUTE.—I can answer that by saying, thus far there has been no difficulty of the kind, and that the practice on the Erie Road makes it very clear and apparent that the heavy engines are the economical ones to use. In 1874 the average train upon the Erie Railway was about 22 cars. The road was then mainly equipped with "American" engines of 8 wheels (of which 4 are drivers) on the various divisions. On the Buffalo division and on the Western division the average load was from 17 to 19 cars, and the average train load, including the empties, was, I think, about 106 tons. In 1876 the road began to put on the consolidation engines. These were carefully limited to an average of 11 000 pounds per wheel, which was somewhat less than the weight then existing upon the "American" engine. And I would say, with regard to the wear of rails, that we have not yet been able to detect any more wear from the wheels of those "consolidation" engines than from the "American" engines which they displaced. The effect of putting those engines has been, I believe, to increase the average train to about 38 cars, and the freight per train to about 228 tons instead of 106 tons. There were, at the beginning, some difficulties apprehended, chiefly from the breaking of trains in two, the pulling out of drawheads, breaking of links and pins, and similar accidents likely to detain the traffic. It was therefore determined to change and to increase the strength of the draw attachments to the car. A stronger drawhead spring was substituted. The drawhead arms were more firmly fastened to the mainsills of the car, the drawhead was increased in strength, the pin and the link were also increased in size, and then pains were taken to prevent, as far as possible, the breaking of trains in two, which, railroad men all know, causes the largest number of minor accidents occurring on railroads. These precautions were found to produce an entire success, and although the trains were about double the former length, the accidents were actually diminished in number; and not only was the useful train load increased, but the expenses of doing the freight traffic were diminished from 0.958 cents a ton a mile, to 0.526 cents a ton a mile, which latter cost the operating accounts show for last year.

CHARLES H. FISHER.—The paper by Mr. Shinn speaks of terminal facilities as one of the elements that enter into this question, and Mr.

Cooper has asked me if I was familiar with the new kind of freight yard, which he calls a patent yard. If the members of the Society have not seen it, perhaps they may be interested in it.

THEODORE COOPER, M. Am. Soc. C. E.—I will say, Mr. President, before Mr. Fisher commences on the subject, that I may be mistaken in saying it was a patent yard. I was not positive that it was patented; my impression is that it was secured by a patent.

CHARLES H. FISHER.—The yard is made by assuming a parallel line to the main track, which all the trains take, by means of reverse curve sidings. These sidings are placed upon an angle and will hold a maximum train of 40 cars or 50 cars, or whatever number constitutes a full train upon the road, and then arrangements can be made, so that upon switching tracks any desired arrangement of the cars can be secured. The idea was suggested on the road with which I am connected, probably two years ago, and the plans perfected, and we have begun to carry it out, although not much has been accomplished as yet.

O. CHANUTE.—I would say that if the members will consult a paper read and discussed before the English Institution of Civil Engineers in 1875*, they will find the style of the yard delineated by Mr. Fisher fully discussed and explained. The English call them "grid-irons," and they generally place two such yards end to end, endeavoring, where it is possible, to select some point on the line where there is some grade of 40 or 50 feet to the mile. Then, by placing a train at the upper end, and sorting one or more cars at a time, they pass them through the first grid-iron, whence a second sorting passes them to a second grid-iron. There were two or three papers read at the time I referred to before the English Institution, which were fully discussed by railroad men, and figures were given showing the enormous traffic which was handled at various points, more particularly at the junction of roads. The cost of handling trains by this method was very much less than by that which exists in this country. I call attention to those papers now to show that the plan is not new. They are published under the head of "Railway Management."

CHARLES H. FISHER.—And the idea was considered favorably?

O. CHANUTE.—Yes, and the result very good. I wish to say that I hope that, in replying to the discussion, Mr. Shinn will at greater length indicate how it is feasible to carry out the very important

* Proc. Institution of Civil Engineers, Vol. XLI., p. 1.

suggestion which he has made to change the method of paying for cars. That is, as he has pointed out, one of the most serious questions which now encumber railroad men in the handling of the rolling stock. A single company may have twenty-five to thirty thousand cars scattered all over the country, and they are paid for mileage at the rate of three-quarters of a cent a mile. They are taken by connecting roads, used as warehouses, and used in local traffic, while the road owning the cars by no means gets an adequate compensation for their use. On the other hand, it has, I think, for the past ten years, been proposed, time and again, to change the method of compensation from the mileage to the per diem basis. No attempt, however, has been made to carry out the reform; the difficulties being of course the lack of an adequate plan, the dread of the roads that they may lose traffic while introducing a reform of that kind, and the opposition of those roads which profit by the present arrangement. I would, therefore, for one, feel very much indebted to Mr. Shinn if he would more in detail indicate how such a reform can be carried out.

William P. Shinn, M. Am. Soc. C. E.—If there is no other gentleman who wishes to discuss the question I will say what I intend to say now. I have been rather disappointed that the criticisms have not been more numerous, and more in detail, upon the subject of the remedy that I proposed for the greatly deficient movement of cars, and the totally inadequate compensation for their use. Mr. Chanute has touched briefly upon the existence of some objections. Every one who knows anything about the subject, of course knows, in a more or less general way, that such objections do exist. Mr. Paine, in his paper, has pointed out more specifically some of the difficulties. I think they can all be met in a practical way, but I am not prepared to-night to go into the summing up of this discussion intelligently. I have only heard the papers read that have been offered in discussion of my paper—have not had a chance to read them myself—and before undertaking to go into the subject, as Mr. Chanute suggests, in greater detail, I should like to have the time to consider the objections that have been offered, and I should also like to have those objections stated further in detail than they have been stated as yet. I knew, as a matter of course, from my own experience in the commercial department of railroad management, that the greatest objections would come from that side. I was of the opinion, when I was connected with it, that there had not been that

attention paid to the management of the commercial department of railroads that its importance demanded. That department has generally been entrusted to men who come up through the office as clerks, and who have had no experience in what could properly be called railroad management; who knew nothing about the practical difficulties to be met with in doing the business on the roads, and who could not appreciate the advantages to be gained by their company from the adoption of certain principles in conducting their part of the business. But I think that has been very measurably reformed since the date that I refer to, when I was engaged in that department. I think it is capable of being still more reformed, and it is, I believe, one of the reforms that must be brought about—that the commercial department must see that it must work for the interest of the railroad as a whole, not merely in a way to produce a certain amount of tonnage, or to secure a certain share of the business that is offered. The practical result to be aimed at in all railroad management is *net earnings*, and that practical result is too largely ignored by the commercial department. As a general rule, that department is not considered by its heads and subordinates to be responsible for net earnings, but simply for *gross earnings*. These questions—this one in particular, that I have alluded to—perhaps its most immediate effect would be upon net earnings; it would ultimately have quite as great an effect upon the gross earnings. As this paper will come up again for discussion at the Annual Convention, which will not come off for five months, I shall be glad if some of the members of the Society who have not yet had time to do so, would consider the subject, and give the Society the benefit of their views upon it, before I undertake to answer these objections. I should like to have all the objections that members can think of. I do not arrogate to myself the ability to meet them all, but I wish to have a chance to try. I am firmly convinced, as the result of my experience, that the present system of payment for the use of cars is wholly wrong. It must be reformed, and I firmly believe that the reform is in the direction that I have pointed out. My calculation as to the rate at which the compensation should be fixed is merely tentative. That may be too high. I do not think it is. But there may be reasons advanced why it should be placed at a lower point. If any gentleman connected with railroad management can advance these reasons, I for one shall be as glad to hear them as any other member of the Society. The ideas that I have advanced in that paper are not

what can be called a "hobby" with me. I am willing to consider any reasons that are advanced against the adoption of that idea, but I do firmly believe that something has to be done, and I think the railroad managers themselves are convinced of that, and it is pretty evident that the adoption of the plan suggested would cure that particular evil. In my own opinion it would be wholly beneficial. I do not know, Mr. Chairman, just how to formulate the suggestion I have made in regard to further time being taken by members to discuss the paper before I sum it up, but I earnestly hope there will be some further discussion and some further criticism before I undertake it.

CHARLES H. FISHER.—I would like to ask Mr. Shinn how he would meet a case where one road refused to take freight cars from another, either from inability or lack of power, or anything of that kind, and the road runs them to the end of its line, ready to deliver them, and then it is obliged to store them in its yard for three or four weeks, or two months perhaps. How is that to be met under your provisions?

WILLIAM P. SHINN.—There are a good many conditions, and that is one of them, that ought never be allowed to arise. When I was managing, to a certain extent, the traffic department of a railroad, I never allowed a blockade to occur to any extent. By proper watching of the traffic a blockade can be arrested in its initial stages. It is entirely possible to do so. It has been done to my knowledge; I have done it myself. But I do know that, as a general rule, no effort is made to do it. The cars are brought in until every yard is full, and then things come to a stop from sheer inanition. I do not call that management. That is one of the things that must be reformed. Whenever a railroad company gets cars to one of its termini that it cannot get rid of, it should certainly stop receiving cars bound for that terminus, or cut off the receipt of cars for that terminus at other points, and by proper care and system that can generally be so well guarded that the number of cars that would be caught in that way would be wholly insignificant.

CHARLES H. FISHER.—This is so interesting a subject, and there are so many members of the Society who have not been heard from upon it, that I would suggest that the matter be laid upon the table for further consideration, so that it may be more fully discussed at the annual meeting.

WILLIAM P. SHINN.—Before closing the present discussion I was about to say that the question has been asked, and it has been suggested

that I should make some remarks upon it just now, in regard to this plan of running engines "first in, first out," with miscellaneous crews. That is one of the reforms that has been undertaken with very great hesitation. I recollect its being proposed fully ten or twelve years ago, and at that time all the railroad men that I heard express any opinion about it said, "It won't do at all; it cannot be done." The experience on the Pennsylvania road has been exactly this, as I am informed by the General Manager. I will say that I had a conversation with him on that subject since my paper was written: They commenced experimenting with it on their middle division, which is a division of low grades, and consequently heavy trains, and they had just the experience that everybody predicted, to a certain extent. Men did not have any interest in the engines, did not take any particular care of them, and an engine would go out on the road, and the engine man that had it then in charge would find some little defect that ought to have been remedied at the end of the previous trip, which would probably delay him for a considerable time in getting through with his train. But that is only the experience that everybody has had to go through who has attempted to change the manner of doing business among what we call "practical men," and I believe it is inevitable. It is on record that when they commenced to build steel ships in the French navy-yard they tried to do the work with the men who had been accustomed to build iron ships. They could not teach them that steel could not submit to torture in the manner that iron would; that it must not be heated so hot; that it must not be turned so sharp; and that in every respect, perhaps, it was a material requiring different treatment, and they had finally to turn out the whole of the iron workers and put in a lot of ship carpenters, because they knew nothing about iron or steel; they were willing to be told; and the narrator says that after they got them fairly taught they had no trouble. Now, reforms of this kind are very much of that nature. On the Pennsylvania road they gradually drew the lines tighter and closer. When they found a man came in off the road with his engine a little out of order, and he did not report it, he was disciplined. The men who took the engines out that had not been reported very soon began to complain and find fault with the man who had made the previous trip, that he had not done his duty, and had, therefore, entailed upon them additional trouble and loss of time. I tried a plan on the Fort Wayne road of using one man to hold another up to his duty in that respect. It

worked very well. We had a great deal of trouble with the setting off of cars. The engine man would tell the conductor that he had one or two more cars than he could haul. He could not make his time. He would not be able to get to the meeting point unless he set them off; and finally he prevailed upon the conductor to let them be side-tracked, and as the traffic was pretty well up to the capacity of the engines, those cars would stand there for two or three weeks before a train took them up. I got an order made that whenever a car was set off at a siding from any cause, except from being out of condition to run, the next train should take that car if it had to leave one of its own. The consequence was that the engine man and conductor of the next train that came along had something polite to say to the engine man and conductor who left that car. And the further consequence was, it was not a month before that business was wholly stopped. Now, very much the same thing took place on the Pennsylvania road. It took a little longer to bring it about, because, as the negligence was not of so pronounced a character, it was not so easy to locate it in all cases. But they found that there was a possibility of divorcing the running of engines from the keeping engines in order, and the men who ran them were required at the end of each trip to make an entry on a slate in the round-house—a positive entry—either that the engine was in good order, or that it was so and so in bad order; and that was not allowed to be neglected. If any engine was reported in bad order after any trip and was not repaired in that particular before going out on the next trip, the round-house foreman was called to account. I do not recollect being told of the length of time that the experiment continued, but it continued until the officers of the company felt that they could adopt the plan. Their freight trains are now run precisely in that way. The engine crew and the train crew are attached to a caboose of a certain number, and the designation of that caboose to go out with a given engine designates the crew for the engine and the train, and it frequently occurs that the crew has no knowledge within ten or fifteen minutes of the time of starting as to what engine they are going to have. They will have the next engine in succession that is in order to go. It may be the next engine in order of coming in, and it may not. The Pennsylvania Railroad Company have now had that system in operation nearly four years, it works entirely satisfactorily, and they have gotten over all trouble in that respect. For their passenger trains they have two regular crews, as Mr. Fisher says they have on the New

York Central, the reason being that the passenger run can generally be made in three and a half to five hours at the most, and it is easy for a crew to make the run out and back within twelve hours, so that both crews can run the engine regularly, starting from the same end of the run. That, of course, is not practicable on freight trains unless the runs were made very short, because of its requiring ten or twelve hours to make an ordinary freight engine run, and it would keep a crew on the road in the neighborhood of twenty-four hours consecutively to make a trip out and back.

CHARLES H. FISHER.—These remarks have suggested another thing that I might mention. On our road at present, as Mr. Shinn has stated, two freight crews are attached to the same engine, and each make their trip over the division, 150 miles and return. A portion of them, however, have been located in the middle of the division, 75 miles, and make their residence there; and it has a decided preference on the part of the men where that has been the case; it enables them to step on the train as it passes that point. They run through to the terminus and return with their engines as soon as possible, so that they can have their lay-off at home. I speak of this as a matter for consideration in determining the best and most satisfactory manner of working the train crews.

CHARLES E. EMERY.—There is one further suggestion, Mr. Chairman. I would ask as to the advisability of inviting those that are not members of the Society, but the freight managers of the trunk lines, to take part in this discussion. There has been enough brought forward to show the necessity of bringing the commercial element directly into this discussion. It would be interesting to hear suggestions from their standpoint. Take this very case of where it was mentioned that the way to stop a freight blockade is not to receive freight. That would work very well where there is only one line between these points. But there may be several competing lines. For instance, the Central going into Boston can only go over the Boston and Albany. It might be better policy for the men who were handling the freight at Chicago to pile it up in the cars than to let it go to rival routes. That is the commercial difficulty that will come in at every phase. I do not think we will secure a thoroughly full discussion and a detailed statement until we get those that manage commercially to enter into the discussion. Vice-Presidents or managers of the freight departments of trunk lines will have something to say in regard to this question which, I think, will be of decided

interest; undoubtedly they will learn something. I have not a particle of doubt of that. Still it would be of more value to all parties.

The SECRETARY.—I may say that we have already asked a number of these gentlemen to enter into this discussion. I know that the paper has excited interest among many of them, but they have not yet sent us any discussion.

ROBERT L. HARRIS, M. Am. Soc. C. E.—During one important part of the discussion, which seems to have come to a close, one point especially attracted my attention, which was the assumption of 50 miles per day for freight cars as possibly reasonable. Mr. Shinn showed us *what could* be done with that rate of movement, and what *is* really done now.

Upon a railroad in the construction of which I was engaged a while ago (I had nothing whatever to do with the management), the run of the cars employed in carrying much of the material was about 1 200 miles. We could count upon those cars every 14 days, including the day necessary for loading, showing a movement of over 90 miles a day. This was a regular performance during track laying.

It was not regular freight, it was construction materials, and the men who at the end of the track were handling that construction freight for track laying, were obliged to unload whenever the trains came in, up to 10 o'clock at night. It was made obligatory that the cars should be reported, and should start on their return the following day. If this was not done, the train despatcher, and through him those at fault, were blamed.

At the other end of the route cars were loaded each day, and a regular rotation of each and all of the cars was necessary in order to provide for the supply of, as well as the demand for, material. Doubtless the reason for this prompt movement of cars was that the railway was short of rolling stock, and promptness became a necessity.

In connection with this regular movement, one matter greatly interested me, small apparently in itself, yet large in results. Here were over 2 000 miles of railway in active commercial transportation, and the business crowded for the construction of both the Texas Pacific Railway west, where over 2 miles of track per day were being laid, and the International and Great Northern Road south to Mexico.

Each station agent and conductor of trains was obliged to report to he train despatcher of his division every evening before 8 o'clock; and

each train despatcher to his division engineer, who collated these reports; which reports were not only of cars upon side tracks, empty or loaded, but of each car moving south or north, with the character of its freight, besides any unusual occurrences. The compiled reports were telegraphed the same evening to the general manager wherever he might be. These reports were not put on a hook as received or filed away without examination, but were thoroughly examined upon receipt each night, and if anything was going wrong the proper corrective was instantly applied.

I was surprised one night when, as a guest in the official car near El Paso, the general manager, H. M. Hoxie, Esq., whom many of us know as one of the most expert in the country, called me to his room and asked, "Would you like to know more about your work (1 100 miles away, near Laredo) than your own telegrams show you?" On my replying affirmatively, he said, "Here is my report of to-night, similar to what I receive every night, and by which I correct immediately anything wrong."

The paper contained reports of the cars upon every division of the road, where they were, whether moving north or south or side tracked, also a report of the main facts, not alone of the operation but also of our work, the construction for the day. He had the cream of whatever was contained in the many minor reports.

In my opinion the telegraph (and its proper use) is one great power for the "Increased Efficiency of Railroads for the Transportation of Freight;" properly formulated daily reports sent thereby, which reports should be immediately and constantly examined, compared and collated, give the managers of railways potent facilities. I believe these points were not touched upon in Mr. Shinn's admirable paper.

WILLIAM P. SHINN.—I might refer to some of my own experiences in that connection. I did not exhaust my experience in my paper. When I took charge of the freight department of the Pittsburgh, Fort Wayne and Chicago Railway, I found a great complaint about the non-arrival of freight in Pittsburgh shipped from Chicago in car-loads—a distance of 468 miles. I found that the usual time was about a week. Occasionally a few cars got through in four days, but quite as often they were fifteen or twenty; and I organized a system of reports, which resulted within three months in bringing those cars through pretty uniformly in forty-eight hours from the time they started to make the trip at Chicago;

that would sometimes be the morning after the day they were loaded. But from the time of starting from there, they came through pretty uniformly in forty-eight hours, and it was very rarely that a car was out four days.

I also at that time found it necessary to organize the handling of cars through to New York in competition with the Lake Shore and New York lines, particularly the lines over the New York Central, where they had the Red and White and Blue lines of through cars, which carried fourth-class freight—that was flour and grain and provisions—while the only line of through cars we had (the Union line) was limited to higher class freight. We had no through cars for fourth-class freight, and as a consequence I found we were losing in comparison with the other lines. I arranged the matter so as to get reports of the movement of those cars, and succeeded in the course of thirty days in so organizing it that we pretty uniformly beat the "colored" lines in our trip to New York, although we had to transfer all of our freight at Pittsburgh. There was nothing extraordinary in the matter. There was nothing done but what can be done on any railroad. And I do not claim any particular credit for it, and only allude to it now as showing that such a thing is entirely possible if somebody will pay attention to it and organize it, and look after it and see that it is carried out.